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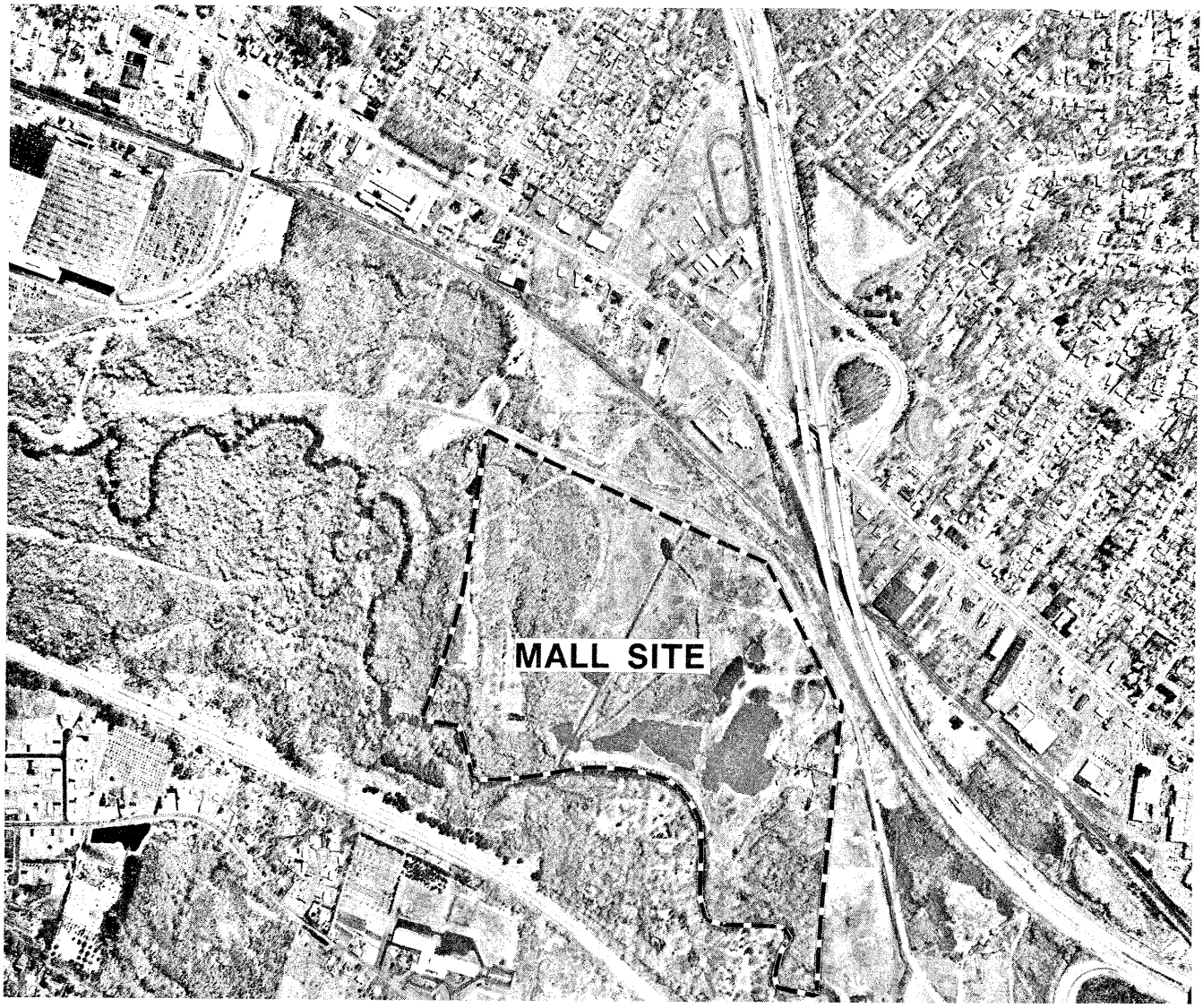
NORTH HAVEN MALL

NORTH HAVEN, CONNECTICUT



1981

US Army Corps of Engineers
New England Division

Appendix D

Sediment and Erosion Control

The material contained in this appendix was prepared for Mall Properties, Inc., by Raymond Keyes Engr. in association with Parsons Brinkerhoff Quade and Douglas, Inc. It has been provided to the Corps of Engineers as information in support of application #13-79-561 for a permit under Section 404 of the Clean Water Act of 1977, and Section 10 of the River and Harbor Act of 1899.

APPENDIX D:

SEDIMENT AND EROSION CONTROL

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Appendix D:

Sediment and Erosion Control

INTRODUCTION

Construction of the proposed North Haven Mall would entail a considerable amount of earthwork, both on-site and off the immediate site. This construction related activity has the potential to cause excessive erosion of soil materials and subsequent deposition of this material in downstream surface waters. An integral part of the proposed Mall development plan is a Sediment and Erosion Control Plan, consisting of both temporary and permanent measures to reduce the overall erosion of materials and to prevent sedimentation of eroded materials in area streams. The overall plan has been developed in accordance with the intent and principles presented in "Erosion and Sediment Control Handbook; Connecticut" prepared by the U.S. Department of Agriculture, Soil Conservation Service, Storrs, Connecticut, 1976.

This Appendix presents the key features of the plan, the proposed method of execution, and the estimated effectiveness of the plan in preventing impacts due to sedimentation and erosion. The assessment of impacts is presented as a comparison of the quantity of material currently eroded from the site with the material eroded during construction and operation of the Mall, with and without the Sediment and Erosion Control Plan.

EXISTING CONDITIONS

The proposed North Haven Mall site consists of approximately 117.5 acres of land bounded on the west by the Quinnipiac River, on the east by the Valley Service Road (Stillman Avenue), to the south by a sand and gravel operation, and to the north by vacant land. The site is generally separated from the River by an earth berm. The site is transected by a drainage channel constructed by the Connecticut Department of Transportation (DOT) as a part of Interstate 91. This channel drains approximately 830 acres upstream of the Mall site. At the south end of the site there are three interconnected ponds which are joined to the Quinnipiac River by a break in a berm. The site has until recently been used for sand and gravel mining south of the DOT channel, and was the source of borrow material for I-91 to the north of the channel. Along the River for the entire length of the site, and along the northern border of the site, the area is basically undisturbed. In those areas where the site has been disturbed, re-vegetation is incomplete, with numerous shallow erosion channels evident.

The site currently drains through the DOT channel in the center portion of the site, through a small natural drainage ditch in the northern portion of the site, through the three ponds at the south of the site, and directly to the Quinnipiac River for areas near the banks.

PROPOSED ACTION

The proposed action consists of constructing a two level Mall with four major department stores and the required on-grade parking. These facilities

would occupy approximately 78 acres of the 117.5-acre site. An additional 16.5 acres would be devoted to a detention pond which would receive all of the off-site drainage currently discharging to the Quinnipiac River through the DOT channel, as well as a majority of the site drainage. Eighteen acres in the northwest quadrant of the developed area would drain directly to the River. The remaining 23 acres, principally the area along the River, would remain undisturbed.

The proposed project includes a Sediment and Erosion Control Plan which consists of utilizing a combination of temporary and permanent structural and non-structural methods to minimize the quantity of soil eroded from the site, and to minimize the delivery of any sediment that does erode from entering the Quinnipiac River. The non-structural feature of the plan is principally a sequenced construction process which would allow areas where earthwork is proceeding to be isolated from the Quinnipiac River, so that storm water is settled prior to discharge to the River. The structural feature of the plan consists of temporary measures to be used during construction, and permanent measures to become a part of the final Mall development.

Construction Sequencing

The phased construction proposed as a sediment and erosion control measure consists of developing portions of the site (see Attachment 1) in such a manner as to minimize the opportunity for materials to erode, and to allow for settling of stormwater runoff prior to discharge to the Quinnipiac River. The sequencing is proposed as follows:

1. The new channel to divert the existing DOT drainage ditch to the detention pond would be constructed, including the culverts under the Valley Service Road, starting at Pond "A" and working upstream. The proposed channel would be top-soiled and seeded, rip-rap protection placed and the channel allowed to stabilize prior to completion of the final step, the actual diversion of the DOT channel.

2. A berm would be constructed at Point "A" shown on Attachment 1, in order to isolate the site from the Quinnipiac River. This berm would be constructed as close to the parking facilities as possible to avoid earthwork near the Quinnipiac River. It would be suitably stabilized by temporary seeding on the eastern side and the placement of permanent topsoil and seed on the western side. At this point, all surface water discharged directly to the Quinnipiac River from areas to be disturbed would be directed to the ponds during the initial phases of construction. Surface water would be directed in a southerly direction through Ponds "A", "B" and "C", allowing for the settlement of sediment. Discharge to the Quinnipiac River would occur at the southwestern corner of the site by means of an existing breach (labeled Point "B" on Attachment 1) which connects Pond "A" to the Quinnipiac River.

3. General construction would commence with the preparation of the building pad, as outlined on Attachment 1. The general construction procedures to be followed are presented later.

In accordance with recommendations of the Soils Engineer, several locations for the building pad area would be surcharged in order to reduce differential

settlement in various areas. It is estimated that the surcharge material would remain for a period of six months and would then be removed and spread over other areas of the site requiring fill.

4. Construction in the northwestern quadrant of the site would begin at the north end and work to the south. Concurrently, the placement of fill required for the widening of the section of Valley Service Road fronting the site would also commence. All exposed earth subject to significant settlement would be temporarily seeded and other areas would be permanently seeded.

5. Grading of the northeastern quadrant of the site would be completed next, in a generally north to south direction. Additionally, widening of the Valley Service Road would be completed in accordance with the construction documents. Areas subject to settlement including the surcharge area would be temporarily seeded, and other exposed earth areas would be permanently seeded. Storm drainage and utility facilities would be installed in areas which are not subject to significant settlement in the northwestern quadrant.

6. The southeastern quadrant of the site would be developed in a manner similar to that of the northeastern quadrant.

7. The work on the southwestern quadrant of the site would then be completed. The work would generally be performed in a north to south direction, including the filling of the existing ponds. The filling of the ponds would be achieved in sections. A berm would be constructed between

Pond "B" and Pond "C". Pond "C" would then be dewatered and filling would commence. Once Pond "C" was substantially filled, the process would continue in a southerly direction to Pond "B", and then to the extent indicated on the construction documents, to Pond "A". Special techniques for the placement of fill in the northern side of Pond "A" would be used to prevent siltation, as this area could not be dewatered. Examples of such techniques include the use of silt screens near the fill discharge area, progressive filling from shore with select material, and the use of "tremie" devices to discharge fill material at the bottom of the water column. The placement of this fill would be controlled through an approval process, whereby the contractors would submit proposed methods for approval by the applicants representative, to meet a performance criteria to be included in the specifications. Specifications will be coordinated with the Corps of Engineers, the Soil Conservation Service (SCS) and the New Haven County Soil and Water Conservation District.

8. A large portion of the fill material for earthwork at the site would be aquired from Pond "A" and the area just south of it to create the detention pond. Upon completion of earthwork, final stabilization of the enlarged detention pond and its edge areas would be completed. Stabilization techniques to be investigated would include vegetation, rip-rap, and the use of applied membranes (non-woven fabric, sprayed emulsions, etc.) The permanent outfall structure would be installed in accordance with construction documents, and the temporary discharge through the southern break in the berm closed off at the pond.

9. Upon final settlement and installation of storm drainage and utility facilities, final stabilization of all areas would occur, beginning in the northwest quadrant and continuing in a clockwise direction to each subsequent section as above.

The necessary construction procedures for the various highway improvements along Washington Avenue (Route 5), Route 22, Mall Drive and the remainder of the Valley Service Road would occur concurrently with the site development work.

The procedures to be used in executing the phased construction described above would be based upon sound construction practices which would minimize erosion and subsequent sedimentation in the Quinnipiac River. These would include: clean-up of the site at the end of every day; scheduling of deliveries of materials, particularly top soil and fill, to avoid stockpiling; and scheduling of site work to minimize the area actively being worked. Structural practices and non-structural methods other than the above described sequenced construction are listed in Table 1. These methods would be required in the contract specifications, and would be controlled through an approval process of the Contractor's proposed application of these measures. Vegetative controls would be coordinated with the New Haven County Soil and Water Conservation District, SCS and the Corps of Engineers. Measures in addition to those listed in Table 1 would be considered if they achieve the same or better effectiveness, or if unanticipated site conditions come to light. A further control process would include the use of an experienced soils engineer on site during construction to assure that all proposed measures are implemented and performed as predicted. The field soil engineer would be empowered to direct the Contractor to make modi-

Table No. 1

Sediment & Erosion Control Measures

Temporary Meausres

Vegetative	Non-Structural	Structural
Seeding	Hay or Straw Bales	Diversion
	Dust Control	Diversion Dike
	Mulching	Sediment Basin
	Gravel	Heavy Use Area
	Traffic Control	Protection

Permanent Measures

Vegetative	Non-Structural	Structural
Topsoil	Land Grading	Detention Pond
Seeding	Benches	Grassed Waterway
Landscaping		Open Drainage Ditches
		Rip Rap
		Paving
		Subsurface Drain
		Storm Water Drain Inlet
		Pipe Spillway

fications to any and all erosion control devices and systems to assure adherence to the performance specifications, and to meet unusual conditions.

General Construction Activities

For each area in which construction is taking place, as outlined in the above discussed sequencing, the following general activities would take place:

1. Temporary diversion ditches would be installed as required to drain the work area with its discharge directed to the detention pond.

2. Each development quadrant would be cleared and grubbed of existing material as indicated on the construction documents. Disposal of material would be to a sanitary landfill.

3. Topsoil, where present on the site, would be stripped and stockpiled in an acceptable location. This stockpile would then be temporarily seeded to minimize sediment production. No excess topsoil would accumulate on this site because the mining operations which have been in progress for a number of years have left little topsoil on the site. Should topsoil be needed for grading and planting, the contractor would be required to supply topsoil in compliance with the construction documents.

4. General earth moving operations would be performed. It is anticipated that two techniques would be utilized in the performance of this work.

First, it is anticipated that enlargement of the existing southerly pond for the detention pond would be accomplished largely by use of hydraulic techniques. An excavation rig would be erected within the boundaries of the existing Pond "A" (Attachment 1) capable of pumping both water and soil materials through a temporary pipe network which would be installed onsite. The pipe network would consist of a loop extending around the perimeter of the work area with a series of "T" connections, each controlled by a valve, at regular intervals. The pipe network would be surrounded by a low berm to prevent discharge from the pipe system from leaving the work area. As the work proceeded in accordance with the construction sequence, the appropriate valve would be activated. The discharge from these lines would be contained within the low berms and would then be directed by a system of shallow swales or natural ditches in a southerly direction, returning to existing Pond "A". In this way, the water level within the pond would be maintained, insuring that the excavation of the material by this technique could continue. Also, any fine sediments not deposited at the fill site would be able to settle out in the pond. As the excavation of the pond and subsequent placement of fill continues, the pipe loop surrounding the work area and the berm protecting it would be raised as required to continue the operation.

The second technique for fill placement would be to use traditional grader methods using fill material from off-site borrow areas. The source of fill material would not be known until a contractor is selected.

The quantity of off-site borrow is estimated to total 488,000 cubic yards. This represents 43 percent of the total fill material (1,143,000 cubic yards) required on the site.

5. As earthwork operations continue, temporary ditches would be maintained to the extent and at the location appropriate, to insure that the work area remained dry and that sediment was directed to designated areas. Areas subject to significant settlement would be temporarily seeded for the three- to six-month settlement period. Also in this phase, permanent seeding of all slopes would take place as each slope area was completed or, if slopes exceed a height of ten feet, the slope would be permanently topsoiled and seeded after the completion of each ten foot increment in height. The applicant would require the Contractor to shape all surface areas at the end of each work day to drain positively to the diversion ditches, and that these ditches be inspected routinely to insure their proper functioning. Areas which could not be directed to the ditches, such as fill slopes along the exterior of the property, would be controlled by staked hay bales, silt fences or other approved means. In addition to the shaping of the graded surface prior to the end of the day's work, the area would also be firmly rolled, sealing the soil as tight as possible to minimize erosion from overnight rains.

In the surcharge areas, when sufficient settlement has been recorded, the subsurface storm drainage and underground utility facilities would be installed in accordance with the construction documents. The applicant would require of the Contractor that all inlets and pipes would be protected during the installation operation and no open pipe be permitted to remain

within an open trench overnight. Pipes would be plugged with a suitable plug and the trench backfilled prior to leaving the work site. Upon completion of the inlet structures, surface water draining to these structures would be filtered through weep holes in the sides of the inlet structures with adjacent gravel backfill, hay bales, and/or silt fences staked around the perimeter of the inlet in accordance with appropriate standards. As the grading, storm drainage and utility operations were completed in each section, the area would be inspected and approved as required in the construction specifications.

Final stabilization would follow installation of storm drainage and utility systems. The final grading, compaction and rolling of the area would be completed as soon as possible in preparation for final stabilization of the area. The appropriate final stabilization for each area would be based on the final intended use for that area as shown on the construction documents. In the case of the building, the building slab would be poured, tested and approved. In the case of the parking area, pavement would be placed. All areas designated to be landscaped would be topsoiled, permanently seeded, mulched and landscaped in accordance with the construction documents. Inspection of all landscaped areas would be conducted each day and appropriate steps taken to insure establishment of this material. All seeding and landscaping would be coordinated with the Corps of Engineer, the SCS and the New Haven Soil and Water Conservation District to assure that the materials used are appropriate for the region and locality, and are visually compatible with the neighboring areas.

As construction progressed, all temporary and permanent sediment and erosion control measures would be inspected on a regular basis. Where required, maintenance and repairs to these facilities would be made immediately. Sediment would be removed from all sediment basins when pre-arranged levels of sediment collection were achieved. Sediment removed from such basins would be mixed with suitable material and used for fill as approved by the Soils Engineer. All temporary sediment and erosion control measures would be disposed of after they have served their purpose in a manner which would not negatively impact the work area or surrounding environs.

Pre-fabricated metal hoods would be installed over the outlet pipes from all drain inlets in order to trap oil, debris and sediment within each individual structure. A regular program of maintenance would be established for the proper cleaning of these structures to insure continued functioning. Cleaning would be by mobile clamshell, carried out by the operating staff of the Mall or by the Contractor on a routine basis. Additionally, the bottoms of each inlet would be constructed with a partial opening filled with gravel to maximize groundwater recharge.

The general maintenance of the various temporary and permanent sediment and erosion control features is described generally above. Once construction of the project was completed, maintenance of the permanent sediment and erosion control measures resulting from the development would become the responsibility of, and be performed by, the maintenance staff of the proposed Mall.

IMPACTS ASSESSMENT

The assessment of impacts associated with sedimentation and erosion caused by the construction of the Mall is performed, first by a comparison of the total gross erosion currently occuring with (1) that which would occur during construction without the proposed sedimentation and erosion control plan, and (2) that which would occur with the proposed plan. Second, a qualitative assessment of the portion of gross erosion entering the Quinnipiac River is also presented.

In the erosion process, the action of falling rain and running water first loosens soils and carries it away from its original position; this is termed gross erosion. The sediment picked up by rainfall and runoff then travels through minor drainageways where a portion of the material settles out. The ratio of gross erosion to that discharged to a major surface water is called the Delivery Ratio. The delivery ratio is a function of the slope of the area under consideration, and the distance from the edge of the drainage area and the surface water body. The flatter the slope and/or the greater the distance, the lower the delivery ratio. The final element of the sedimentation and erosion process is the trapping of eroded material by impoundments; this is termed the trap efficiency. The larger a pond (volume, surface area, and length from inlet to outlet), the greater the trap efficiency.

Gross erosion is a well-defined process determined by the erosive energy of the rain in the region, the type of soil (physical characteristics), the length of the basin from receiving water to basin edge, the average slope of the basin, and the surface treatment (i.e., vegetated, paved or bare earth).

The delivery ratio and trap efficiency, on the other hand, are not as well defined and are generally more site specific. Methods to compute delivery ratio and trap efficiency reported in the literature vary widely in their results. For this reason, the impact assessment is based quantitatively on the gross erosion, and qualitatively on the characteristics of the site which would effect the delivery ratio and trap efficiency.

The gross erosion was computed using the Modified Universal Soil Loss Equation: (Design of Sediment Retention Basins, Chen, 1975)

$$A = RK(LS)\ CP$$

where:

A = the computed gross soil loss expressed in tons per unit area per unit time.

R = Erosive energy of the rain. For the North Haven area, this has a value of 150. (Chen, 1975)

K = Soil erodibility factor, which differs for each type of soil.

L = The slope length factor: a ratio of the soil loss from the site to a standard slope gradient.

S = The slope gradient factor: the ratio of soil loss from the site gradient to that of a standard slope.

C = Cropping factor: the ratio of soil loss from the site with its vegetation patterns to a field in fallow condition.

P = Erosion control practice: the ratio of soil loss with different practices to the same area without erosion control.

The soil types and their erodability factors were derived from the Soil Conservation Service, and have been presented in the Appendix A: Geology and Groundwater Resources, Soils and Topography. The other factors used in the modified universal soil loss equation were derived from information contained in the "Erosion and Sediment Control Handbook; Connecticut" prepared by the U.S. Department of Agriculture, Soil Conservation Service, Storrs, Connecticut, 1976.

The gross erosion from the areas of the site which would be disturbed (i.e., 78-acre site for the buildings and parking areas and the 16.5-acre area for the detention pond) were computed and are presented in Table 2. These results show that for the areas of the site which would be disturbed, the existing gross erosion would be reduced by 62 percent during construction, resulting from the sediment and erosion control plan. After construction was completed and the Mall was in operation, the reduction of gross erosion from existing conditions would be 89 percent. In the 23-acre undisturbed area, there would be no change from existing conditions.

The delivery ratio of the site is judged to be slightly lower for existing conditions than for the site under development or the completed Mall. The physical characteristics of the site lead to this conclusion. First, the slope of the drainage on the existing site is generally flatter than would exist during construction and after completion of the Mall. This results because the temporary and permanent drainage facilities are designed to assure positive drainage through adequately sloped pipes and channels, thereby promoting delivery of sediment. On the other hand, the inlet structures for the final site drainage work are designed to trap sediment prior to entering the pipes.

Table No. 2

Comparative Rates of Gross Soil Erosion

A. 78 Acre Site (Proposed Parking Area, Buildings & Landscaping)

	Estimated Soil Loss
Existing Conditions	242 c.y./yr.
Total Site Denuded Without Erosion Control Management	7250 c.y./yr.
Total Site Disturbed With Erosion Control Management (During Construction)	125 c.y./yr.
Total Site After Development With Erosion Control Management	26 c.y/yr.*

B. 16.5 Acre Detention Area

Existing Conditions	372 c.y./yr.
Total Area Disturbed With Erosion Control Management (During Construction)	110 c.y./yr.
Total Area After Development With Erosion Control Management	44 c.y./yr.

* Approximately 25% of this volume would be transported offsite by the northwest portion discharging directly into the Quinnipiac River. The remaining eroded portions would contribute to the detention pond for settlement and recovery.

Additionally, the relocation of the outlet from the center of the site to the southern end of the site increases the length of travel of stormwater, also decreasing the delivery ratio for the completed site.

The trap efficiency is judged to be significantly greater for the proposed Mall with the sediment and erosion control plan than for the existing site.

Under current conditions, the majority of stormwater passing through the site (approximately 85 percent) flows through the DOT channel, which traverses the site without any significant impoundments (there is a pond of approximately 1/3 acre just west of the Valley Service Road, and an approximately 1-acre pond near the River on the DOT Channel). This allows little opportunity for sediment from the upstream drainage area to be trapped prior to discharge to the Quinnipiac River. During construction and after development, however, all of this flow would be passed through the detention pond, resulting in significant removal of sediment prior to discharge into the Quinnipiac River. Estimates of the removal efficiency of this detention pond range from 50 percent (Water Pollution Aspects of Street Surface Contaminant, Sartor and Boyd, 1972)to 95 percent (Chen, 1975).

On the basis of the quantitive analysis of gross erosion reduction from the site, both during and after development of the Mall, and the qualitative assessment of the delivery ratio and trap efficiency under these two conditions, it is concluded that both during and after construction, the total sediment delivered to the Quinnipiac River would be significantly less than is experienced with the site in its current condition.

UNAVOIDABLE ADVERSE IMPACTS

Implementation of the proposed sedimentation and erosion control plan would result in an overall improvement in the suspended solids condition in the Quinnipiac River, both during and after construction. Construction of the 16.5-acre detention pond, an integral part of the erosion control plan, would increase the surface waters on the site by up to 6.5 acres. Since this pond provides free access for anadromous fish, the proposed pond would mitigate impacts on these species.

The maintenance of permanent measures (i.e., periodic removal of accumulated sediment from inlet structures and the detention pond) would result in solid materials for disposal at a landfill. Since this material is primarily soil, the material could be used as cover material at the town landfill and, therefore, would not represent an adverse impact.

IRRETRIEVABLE AND IRREVERSIBLE COMMITMENT OF RESOURCES

The creation of the detention pond as the basic water quality control feature would result in the dedication of 16.5 acres of the site to surface waters, compared to the approximately 10 acres currently existing on the site, thus creating approximately 6.5 acres of surface waters.

MITIGATING MEASURES

The proposed sediment and erosion control plan presented herein would fully mitigate any increase in erosion and subsequent sedimentation in the

Quinnipiac River. Additionally, the discharge of off-site stormwater flows through the detention pond would improve the quality of this stormwater flow, further reducing the suspended solids discharged to the Quinnipiac River.

POINT "B"

POINT "A"

QUINNIPIAC RIVER

POND "A"

POND "B"

POND "C"

MACY'S

MACY'S

J.C. PENNEY
L.L. ELEV. 16.0
U.L. ELEV. 33.5

J.C. PENNEY
L.L. ELEV. 16.0
U.L. ELEV. 33.5

ENCLOSED MALL
L.L. ELEV. 16.0
U.L. ELEV. 33.5

ENCLOSED MALL

ENCLOSED MALL

SEARS
L.L. ELEV. 16.0
U.L. ELEV. 33.5

APPROX. EXTENT OF BUILDING PAD PREPARATION

G. FOX
L.L. ELEV. 16.0
U.L. ELEV. 32.5

G. FOX

FREE STANDING BUILDING

INTERSTATE ROUTE #91

VALLEY SERVICE ROAD

VALLEY SERVICE ROAD

PENN CENTRAL TRANSPORTATION CO.

PROPOSED MALL DRIVE

NORTH HAVEN MALL
VALLEY SERVICE ROAD
NORTH HAVEN, CT.

DIAMOND REYES ENGINEERS, P.C.

SITE PLAN

SCALE 1"=100'
DATE 12-3-80
DRAWN BY JBA
CHECKED BY KBM
JOB NO. 2819
DRAWING NO. FIGURE No. 1

APPENDIX E
Stormwater Management

NORTH HAVEN MALL

NORTH HAVEN, CONNECTICUT

1981

US Army Corps of Engineers
New England Division

Appendix E

Storm Water Management

The material contained in this appendix was prepared for Mall Properties, Inc., by Raymond Keyes Engr. in association with Parsons Brinkerhoff Quade and Douglas, Inc. It has been provided to the Corps of Engineers as information in support of application #13-79-561 for a permit under Section 404 of the Clean Water Act of 1977, and Section 10 of the River and Harbor Act of 1899.

APPENDIX E

STORM WATER MANAGEMENT

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APPENDIX E: Storm Water Management

INTRODUCTION

This appendix presents the hydraulic analysis of stormwater at the proposed North Haven Mall site. Stormwater flows generated from the site and stormwater from upstream areas which flow through the site are analyzed for three conditions: existing conditions; assuming construction of the Mall with no stormwater controls; and for the Mall with the proposed Stormwater Management Plan. This plan includes all off-site and on-site drainage improvements, as well as a proposed detention pond.

The analysis examines the change in flows that would result from the construction of the building and parking facilities, and the resultant flows entering the Quinnipiac River during and after construction of the Mall. The impacts of these resultant flows are also assessed for possible impacts upon flooding of the Quinnipiac River. The overall analysis of flooding for the Quinnipiac River is presented in Appendix F: Quinnipiac River Flood Study.

EXISTING CONDITIONS

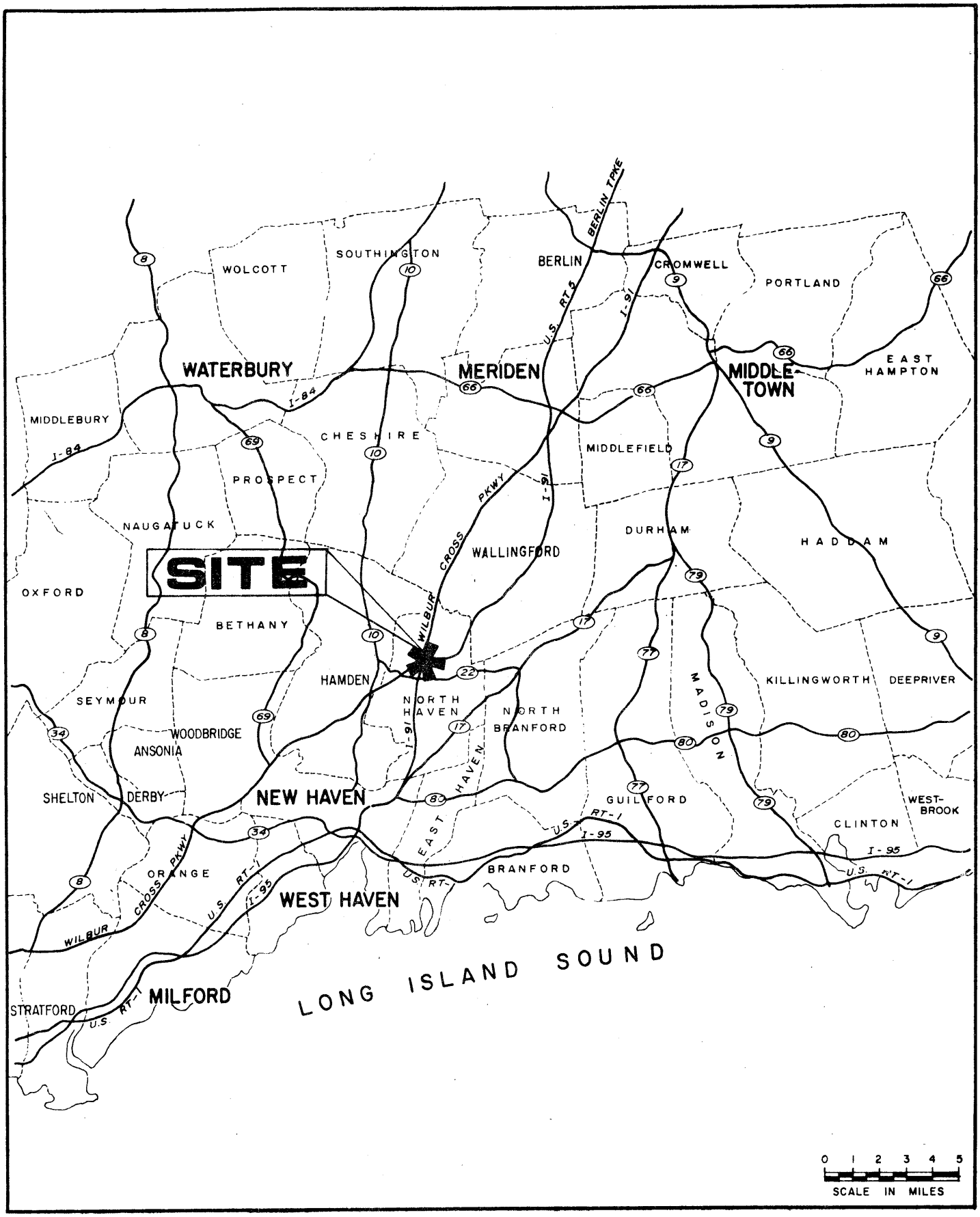
The proposed site for the North Haven Mall is an approximately 117.5-acre parcel located entirely in the Town of North Haven, approximately eight miles north of the City of New Haven at Exit 12, Interstate 91 (Figure 1). The site

is bounded on the west by the Quinnipiac River, on the east by Valley Service Road (Stillman Avenue), on the south by an active sand and gravel operation and to the north by an undeveloped parcel of industrially zoned land. Further to the north (approximately 1/2 mile) is the Pratt and Whitney facility. (Figure 2). Valley Service Road is a cul-de-sac which is currently the only vehicular access to the site. This road connects the site to Route 22 approximately 3,400 feet south of the site, and dead-ends some 2200 feet north of the site.

The site is generally flat, having been used for sand and gravel mining operations, as well as for borrow to construct Interstate 91. It is transected by a drainage channel constructed by the Connecticut Department of Transportation (DOT) when Interstate 91 was built. This channel drains an area of approximately 830 acres east of the site, including portions of I-91. To the north of the DOT channel is the area used for borrow for I-91. In this area, natural grades exist only at the extreme northern portion of the site and as a berm left along the banks of the Quinnipiac River. There is a pond connected to the Quinnipiac River by a break in the berm at the northwestern portion of the site.

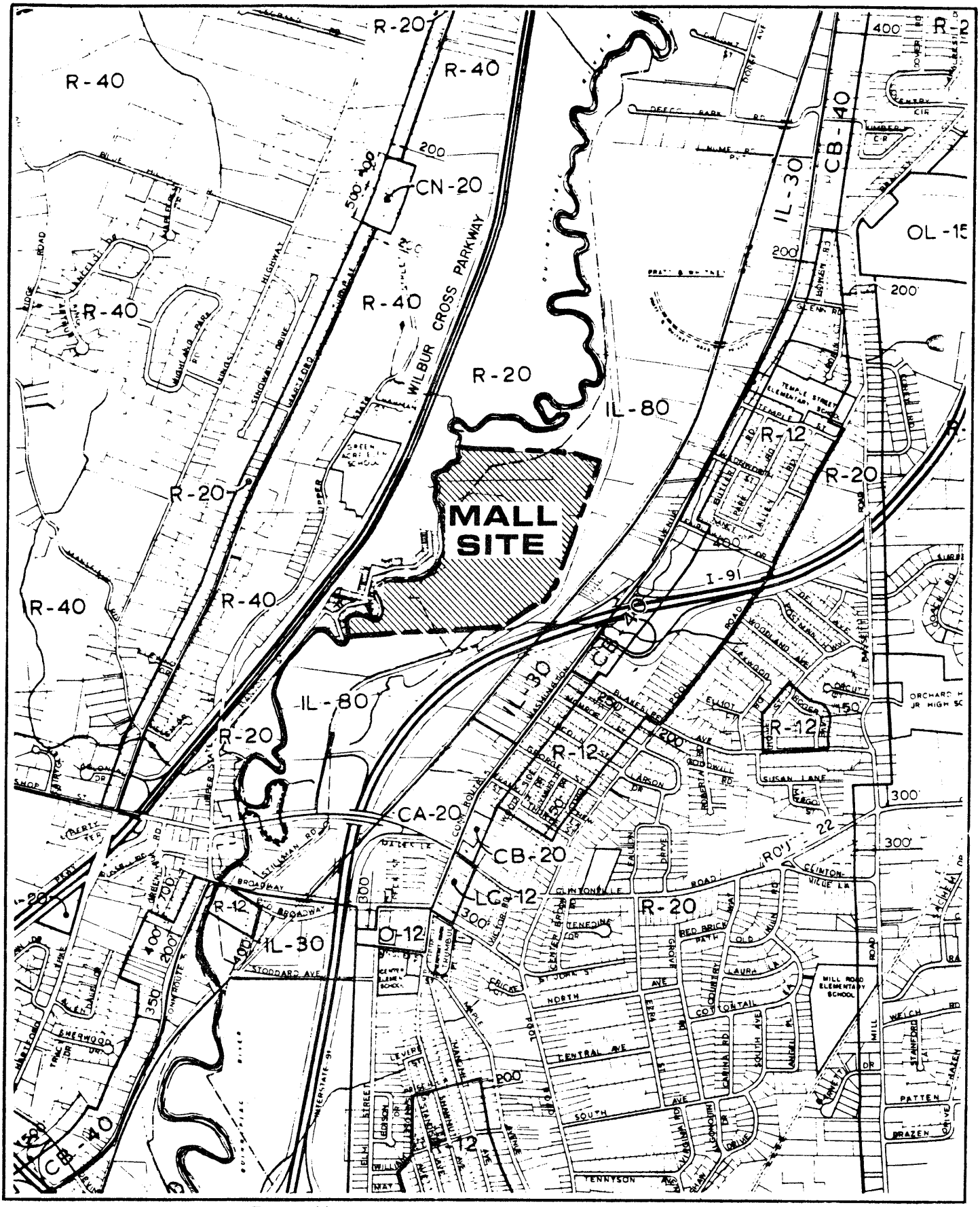
South of the DOT channel is the area used, until recently, for sand and gravel mining operations. This area is characterized by a series of interconnected ponds in the southwestern quadrant of the site. These ponds are connected to the Quinnipiac River by a break in the berm. The extreme southwestern corner of the site is undisturbed.

The total existing drainage area discharging storm water through the site is some 921 acres, divided into three distinct sub-drainage areas (Attachment



North Haven Mall
Valley Service Road
North Haven, Connecticut

Figure 1
Regional Location



Source: Town of North Haven Zoning Map

North Haven Mall
Valley Service Road
North Haven, Connecticut

Figure 2
Site Location

1). At the upstream (east) portion of this drainage area is an area of approximately 795 acres which contributes to the twin 84-inch diameter culverts passing under Interstate 91. Between Interstate 91 and Valley Service Road is an area of approximately 33 acres which, together with the 795 acres east of I-91, discharges through a box culvert under Valley Service Road to the DOT drainage channel. The third sub-basin consists of portions of the project site.

PROPOSED ACTION

Construction of the proposed North Haven Mall would result in approximately 78 acres of the total 117.5 site acreage being largely covered with buildings and paved parking areas. An additional 16.5 acres at the southern portion of the site would be utilized to create a detention pond. The remaining 23 acres of the site would be left undisturbed (Attachment 2).

The 117.5-acre site is divided into three drainage areas: the northwestern quadrant, consisting of some 18 acres, which would discharge to the river; and the northeastern and southern portion of the site, consisting of some 60 acres, which would discharge to a 16.5-acre detention pond. The remaining 23 acres are largely undisturbed areas along the Quinnipiac River and the boundaries of the site, discharging directly to the river.

The proposed Stormwater Management Plan consists of the following major elements:

(1) Creation of a 16.5-acre detention pond at the southern portion of the site, including fencing for safety and outlets designed to allow

free passage of fish between the Quinnipiac River and the pond, and landscaping.

(2) Construction of a stormwater drainage system to direct runoff emanating from roof drains, parking areas, and road modifications along Valley Service Road to the detention pond. The northwestern quadrant of the site, consisting of approximately 18 acres, would be discharged directly into the Quinnipiac River through a piped drainage system.

(3) Diversion of the DOT drainage channel to the southern portion of the site in order to discharge into the detention pond. This improvement would require the construction of a culvert structure under Valley Service Road.

(4) The use of open bottomed inlet structures (catchbasins) to permit infiltration of stormwater into the groundwater system.

(5) The addition of hoods on exit pipes on all inlet structures to trap oil and grease and other floatables from the stormwater prior to discharge to the detention pond or Quinnipiac River.

Off-site improvements associated with the Mall (i.e., construction of Mall Drive, and widening of Valley Service Road) are considered in the analysis since the majority of these areas discharge stormwater through the DOT drainage channel. Portions of the Valley Service Road south of the site to Route 22 were not considered, since the total area of new pavement is negligible in relation to the area through which it discharges. The proposed jughandle from

Route 22, which involves a minimum amount of surface area, was not specifically analyzed for stormwater impacts since this modification has not yet been designed by the Applicant, and thus, details of the drainage system and any mitigating measures contemplated are not known. It is anticipated that this change would incorporate a detention facility to avoid increased flows to the Quinnipiac River. The detention facility would be incorporated into the interior of the jughandle with flow controlled by sizing of the outlet pipe. The discharge would be to the Quinnipiac River by way of existing local drainage channels.

IMPACT ASSESSMENT

Methodology

The stormwater impact resulting from construction of major facilities such as the North Haven Mall is an increase in total volume and peak rate of flow due to the reduction in pervious areas. In order to assess the impact of the North Haven Mall on stormwater discharge from the local drainage area discharging through the project property, the stormwater flows are computed first for current conditions, next with the Mall, and finally with the proposed Stormwater Management Plan.

The method utilized to develop the computed stormwater flows is the U.S. Soil Conservation Service Method as presented in the "National Engineering Handbook: Section 4, Hydrology" (1972), "Technical Release No. 55: Urban Hydrology for Small Watersheds" (1972), "Addendum to Technical Paper No. 55 ENG-ND-8: Urban Hydrology Tabular Discharge Tables" (1978), "TSC Technical Note-Engineering-UD-20" (1972), and "Addendum to UD-20" (1974). Inflow hydrographs for various

sub-drainage areas were generated using the tabular method with the routing of flows through the detention pond accomplished by use of the storage indication method. All drainage areas were taken from existing maps of the site and environs, supplemented by field inspections. Soil maps were obtained from the Soil Conservation Service.

Assumptions

In performing the analysis of stormwater flows from the entire drainage area passing through the Mall site, a number of assumptions were made relative to the details of the area. These assumptions and their effects upon the results of the analysis are presented below.

(1) Calculations of square footage of off-site modifications, including construction of Mall Drive and widening of Valley Service Road, were not performed. These improvements contribute for the most part to the flows passing through the site via the DOT drainage channel. Computations of flows from these sub-basins employ coefficients which are indicative of overall development patterns rather than the exact square footage and permeability of the area under consideration. Since the total acreage in question (approximately 6 acres) is less than one half of 1 percent of the total area upstream of the proposed Mall site, this assumption is well within the range of accuracy of the coefficients employed. The effect of this assumption would be to reduce the computed peak flow by approximately 0.2%.

(2) All flows generated from off-site sources arrive at the site unrestricted. This includes flows passing through the twin 84-inch culverts under I-91, and those passing under Valley Service Road in the relocated culverts. A check of peak flows from these areas with the carrying capacity of the existing culverts confirms the validity of this assumption. The effect of the assumption, were it not valid under all circumstances, would be to reduce peak flows at the site. Therefore, the analysis assumes worst-case conditions. Since the Valley Service Road culverts would be relocated, they would be designed to accommodate the flows computed in this analysis.

(3) Storage provided by the parking areas, piped drainage system and along the relocated DOT channel were not considered in computing the attenuation effects of the detention pond. The effect of this assumption on the results of the analysis is to predict higher peak flows than would actually occur.

(4) Time lags were not considered in routing flows from various subdrainage areas contributing to the detention pond. In fact, the peak flow from areas closer to the pond would precede the peaks from other drainage areas. Because of the small size of the drainage area under study, these time lags would be small. The effect of

this assumption is to increase the computed peak flow arriving at the detention pond.

Overall, the assumptions used in this analysis, as well as the conservative nature of the computation procedure, result in higher predicted peak flows than would likely occur at the site.

Results

The computed flow characteristics for the drainage area discharging through the proposed project site are presented in Table 1. These flows include the area east of I-91; the site, including the northwest portion; and the area between the site and I-91.

The after-development flows entering the detention pond were computed considering the modifications to the site, and are also presented in Table 1. The changes in stormwater flow due to the Mall construction are a reduction in the time to reach peak flow, and a large increase in peak flows, particularly during those storms that occur most frequently.

TABLE 1

Stormwater Discharge Characteristics:
Pre-Development and Post-Development
Without Controls

Frequency Rainstorm	Pre-Development		Post-Development	
	Time to Peak (hrs)	Peak Discharge (cfs)	Time to Peak (hrs)	Peak Discharge (cfs)
2 Year	13.0	140	12.0	331
10 Year	13.0	327	12.0	588
50 Year	13.0	553	12.0	793
100 Year	13.0	699	13.0	955

Based upon existing and post-development peak flows, and considering the land available for a detention pond, a trial-and-error procedure was used to design the detention pond. The criteria used in the design were:

- Create reductions in the peak flows, if possible, for all storm frequencies to levels below those currently experienced at the site.

- Maintain free passage of anadromous fish to allow use of the pond for spawning.

- Maintain sufficient water in the pond during dry periods to allow use by anadromous fish for spawning.

These criteria are not fully compatible, in that allowing for fish passage requires direct openings between the pond and the Quinnipiac River. Such openings do not enhance the attenuation of the small stormwater flows that occur most frequently.

The resulting detention pond design has a bottom elevation of -25 (MSL) feet (as a result of proposed excavation for fill material) with an emergency overflow elevation of +14.0 feet. The outlet of the pond consists of twin 48-inch, smooth flow asphalt-coated, corrugated metal culverts set at an invert elevation of +3.0 feet in the Quinnipiac River, and +3.5 feet in the pond. Mean water elevation in the Quinnipiac River at this point and thus in the pond is approximately elevation +5.0 feet, which allows for free passage to spawning fish from the Quinnipiac River. The normal water depth in the pond of 30 feet would allow fish to utilize the pond under all flow conditions in the Quinnipiac River.

Based upon on the detention pond design and the computed post-development flow characteristics, the outflow from the detention pond was determined as presented in Table 2. These results show a reduction in peak outflow ranging from 50 to 56 percent, with the pond overflowing only during the largest storms. Considering the storage in portions of the parking areas (beginning at elevation 12.0 feet), the reductions would be even greater during larger storm periods.

TABLE 2

Discharge Characteristics of Detention Pond
North Haven Mall

Storm Frequency (yrs)	Peak Inflow Time (hrs)	Peak Inflow Discharge (cfs)	Peak Outflow Time (hrs)	Peak Outflow Discharge (cfs)	Peak Reduction (%)	Pond Elev.* (feet)	Stor. Provided Acre Feet
2	12.0	331	14.2	144	56	7.4	26.2
10	12.0	588	14.4	265	55	10.3	61.1
50	12.0	793	14.6	345	56	13.3	99.5
100	13.0	955	14.4	477	50	14.5	115.5

* NOTE: Emergency spillway is set at elevation 14.0 feet.

To compare the total post-development stormwater peak flows to existing conditions, the outflow from the northwestern quadrant which does not flow through the detention pond must be added to the pond outflows presented in Table 2. These totals are presented in Table 3 along with the predevelopment discharge characteristics.

TABLE 3

Comparison of Pre-development and
Post-development Flows Entering the
Quinnipiac River from the
North Haven Mall Site

Frequency Storm	Pre-Development		Post-Development	
	Time (hrs)	Discharge (cfs)	Time (hrs)	Discharge (cfs)
2 Year	13.0	140	14.4	146
10 Year	13.0	327	14.6	269
50 Year	13.0	553	14.4	350
100 Year	13.0	699	14.2	483

This comparison shows a reduction in the overall stormwater flow to the Quinnipiac River from the site for all storms except the smallest analyzed (2-year frequency), which would result in a increase in peak flow of less than 5 percent. The increase results from the conflicting criteria of flow attenuation and free passage of fish used in designing the retention pond. Any refinement of the design of the pond to reduce the peak flows for small storms would adversely effect the attenuation of larger storms which would have more serious impacts. This increase is not significant in its impact upon flooding in the Quinnipiac River, as explained below.

The impacts of the Mall development upon flooding in the Quinnipiac River are presented in Appendix F: Quinnipiac River Flood Study. There is not a direct relationship between the peak flows presented above and the flows presented in the flood analysis since the return period (frequency) for flooding is not the same as the rainstorm frequency applicable to and used in the local drainage

area analysis for stormwater management. However, several observations can be made relating the two events. First, the resulting peak flow to the Quinnipiac River is attenuated for all but the lowest frequency rainstorms. Although this low frequency rainfall (2-year) could occur simultaneously with the high frequency floods (100-year), this would not create serious problems. The increase in flow from the site is only 6 cubic feet per second in this case, which represents an approximately 1/10 of 1 percent increase in peak river flows at the 100-year flood. Second, and more importantly, the peak flow from the drainage area contributing to the Mall site occurs between 12 and 15 hours after the onset of a rain, while the flood peak occurs considerably later. Therefore, the peaks are not additive and there is no significant impact.

Conclusion

It is concluded from the above analysis that the Stormwater Management Plan proposed as a part of the North Haven Mall would have no adverse impacts upon flooding in the Quinnipiac River, and would in fact result in a reduction in flows from the site and an 830-acre area flowing through the site to the River.

UNAVOIDABLE ADVERSE IMPACTS

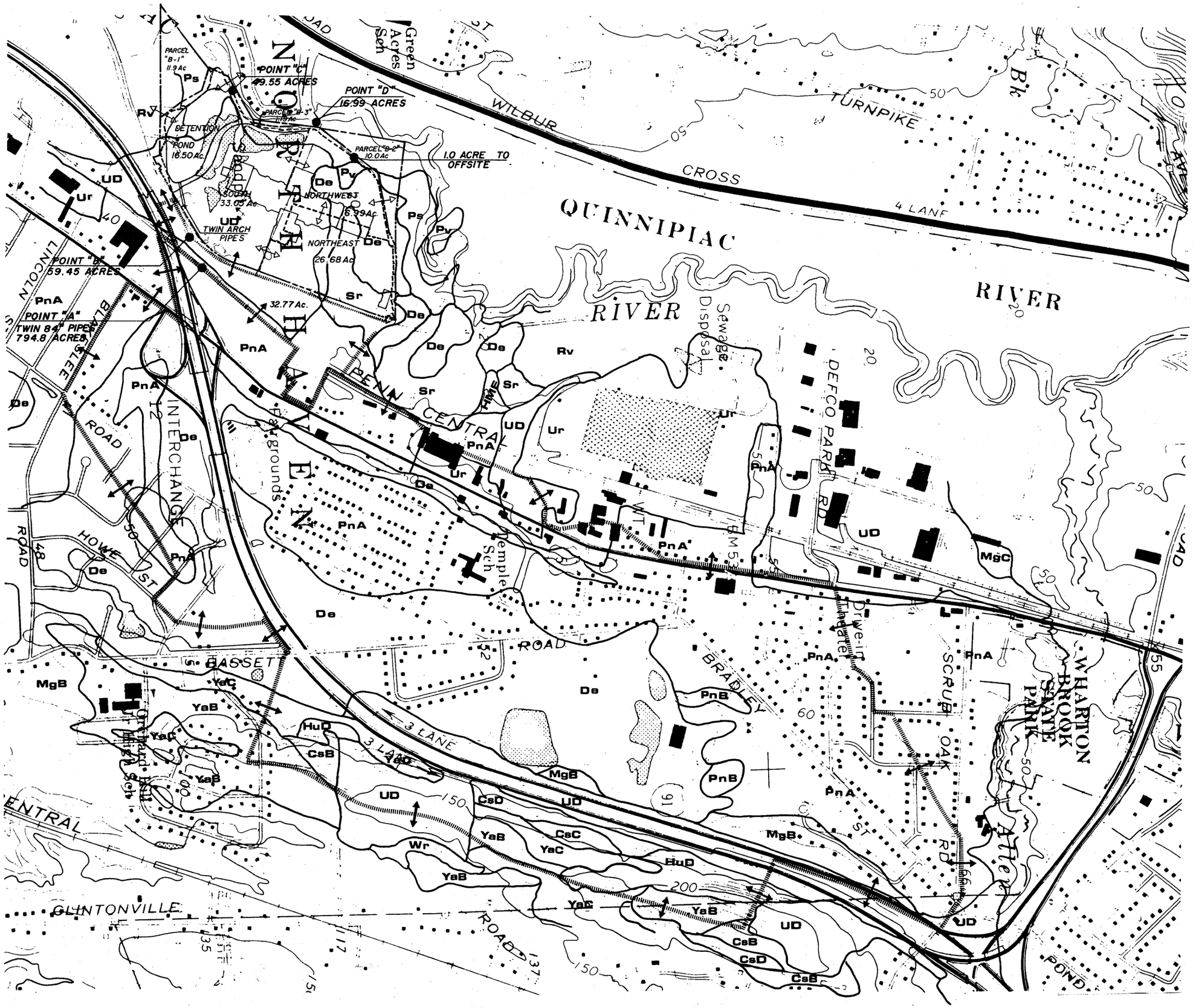
With the proposed Stormwater Management Plan, the development of the North Haven Mall would have no adverse impacts from stormwater flows emanating from the site or contributory areas discharging through the site.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The commitment of resources associated with stormwater consists of the 16.5 acres of land devoted to a stormwater detention pond. Currently, there are three major ponds in the vicinity of the proposed detention pond of approximately 10 acres. The detention pond would increase surface waters on the site by up to 6.5 acres.

MITIGATING MEASURES

The detention pond proposed is a mitigating measure which effectively reduces and nearly eliminates adverse impacts from increased stormwater generation resulting from the Mall construction.



REVISIONS

NO	DESCRIPTION	DATE

SOIL CLASSIFICATION

CsB	CHESHIRE FINE SANDY LOAM, 3-8% SLOPES
CsC	CHESHIRE FINE SANDY LOAM, 8-15% SLOPES
CsD	CHESHIRE FINE SANDY LOAM, 15-25% SLOPES
De	DEERFIELD LOAMY FINE SAND
HME	HINCKLEY AND MANCHESTER SOILS, 15-35% SLOPES
HuD	HOLYOKE-CHESHIRE COMPLEX, 15-35% SLOPES
MgB	MANCHESTER GRAVELLY SANDY LOAM, 3-8% SLOPES
MgC	MANCHESTER GRAVELLY SANDY LOAM, 8-15% SLOPES
PnA	PENWOOD SANDY LOAM, 0-3% SLOPES
PnB	PENWOOD SANDY LOAM, 3-8% SLOPES
Ps	PODUNK FINE SANDY LOAM
Pv	PODUNK VARIANT SILT LOAM
Rv	RUMNEY VARIANT SILT LOAM
Sr	SCARBORO MUCK
UD	UDORTHENTS, SMOOTHED
Ur	URBAN LAND
Wr	WILBRAHAM SILT LOAM
YaB	YALESVILLE FINE SANDY LOAM, 3-8% SLOPES
YaC	YALESVILLE FINE SANDY LOAM, 8-15% SLOPES

LEGEND

EXISTING DRAINAGE DIVIDE

PROPOSED DRAINAGE DIVIDE

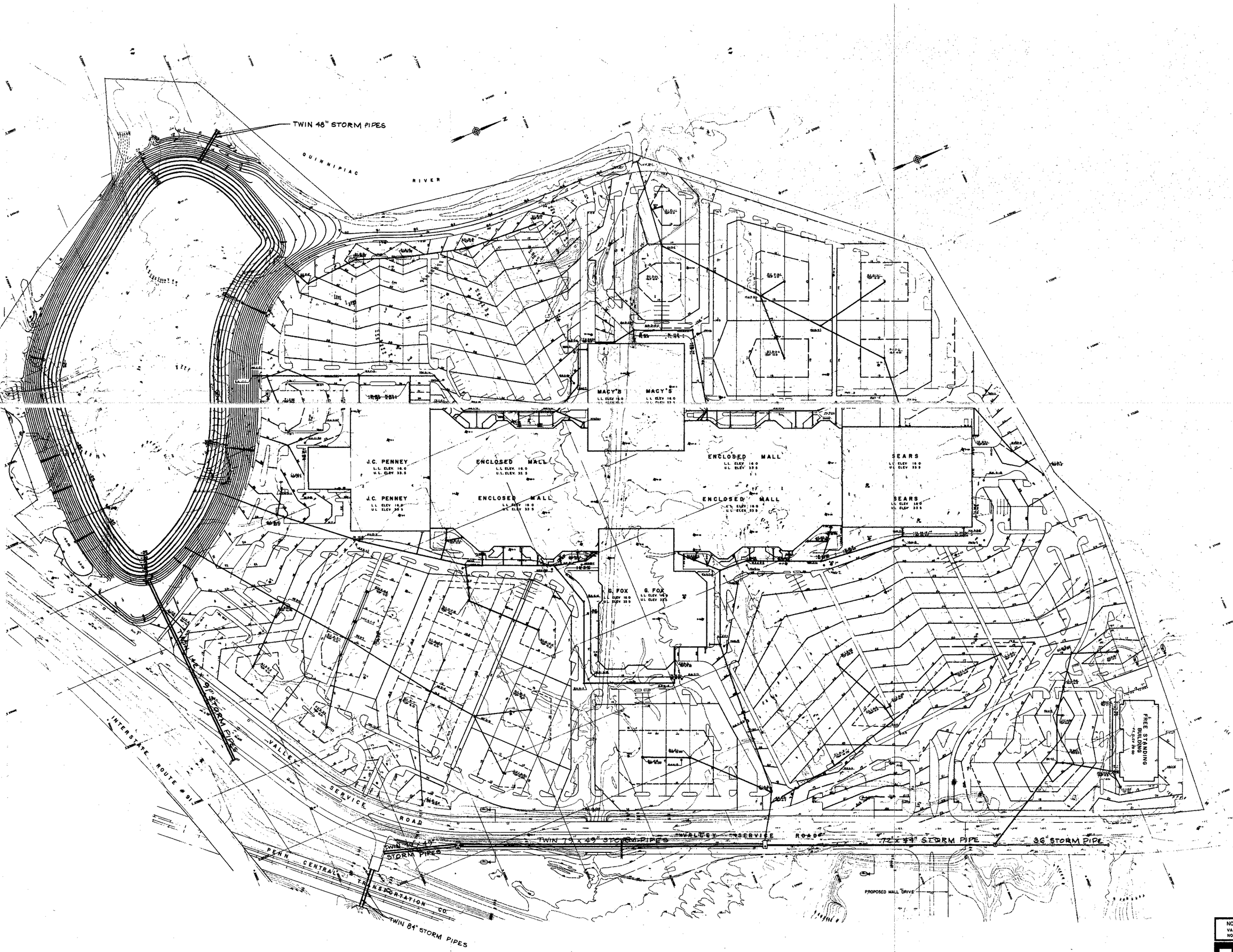
MALL PROPERTIES INC.
635 MADISON AVENUE
NEW YORK, NEW YORK 10022

NORTH HAVEN MALL
VALLEY SERVICE ROAD
NORTH HAVEN, CONNECTICUT

RAYMOND KEYES ENGINEERS P.C.

DRAINAGE AREA & SOIL CLASSIFICATION MAP

DATE	12/4/80
DRAWN BY	C.I.
CHECKED BY	J.E.A.
JOB NO.	2819
DRAWING NO.	ATTACHMENT 1



NORTH HAVEN MALL
VALLEY SERVICE ROAD
NORTH HAVEN, CT.

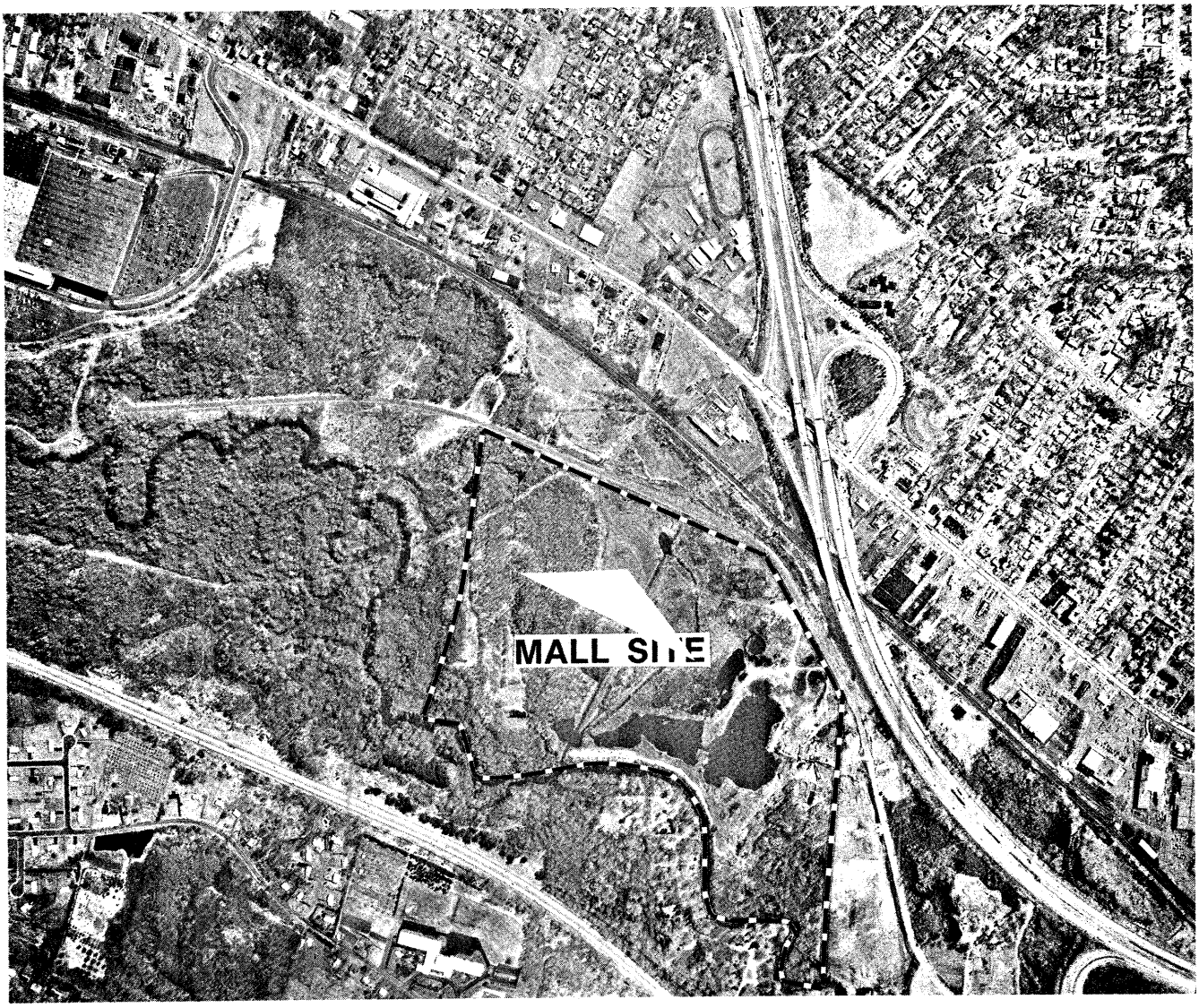
TITLE
SITE GRADING & DRAINAGE PLAN

SCALE:	1" = 100'
DATE:	12/4/80
DRAWN BY:	J.E.A.
CHECKED BY:	K.E.M.
JOB NO.:	2819
DRAWING NO.:	ATTACHMENT 2

APPENDIX F
Quinnipiac River Flood Study

NORTH HAVEN MALL

NORTH HAVEN, CONNECTICUT



1981

US Army Corps of Engineers
New England Division

Appendix F

Quinnipiac River Flood Study

The material contained in the appendix was prepared for Mall Properties, Inc., by CE Maguire, Inc., in association with Parsons Brinkerhoff Quade and Douglas, Inc. It has been provided to the Corps of Engineers as information in support of application #13-79-561 for a permit under Section 404 of the Clean Water Act of 1977, and Section 10 of the River and Harbor Act of 1899.

APPENDIX F:

QUINNIPIAC RIVER FLOOD STUDY

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APPENDIX F:

QUINNIPIAC RIVER FLOOD STUDY

INTRODUCTION

The development of the proposed North Haven Mall, located along the Quinnipiac River in the Town of North Haven, would raise the current elevation of the site considerably, with possible impacts upon the flood regimen of the river. This report presents the analysis of existing flooding of the river and the impacts, both upstream and downstream, of the Mall construction.

This report analyzes the impact of the proposed Mall development upon flooding in the Quinnipiac River in three ways: by increased rates of flow generated on the site, the result of paving a large portion of the site; by restricting the flow of water as it passes the filled site, creating increased water level upstream of the site; and by the loss of storage at the site due to filling, resulting in higher peak flows (and subsequent water levels) downstream of the site. The first issue, increased flows from the site, is analyzed in detail in Appendix E: Stormwater Management. The latter two issues, upstream and downstream flooding, are analyzed in this Appendix.

EXISTING CONDITIONS

The proposed North Haven Mall site is a 117.5 acre parcel located wholly within the Town of North Haven. The site is bounded on the west by the Quinnipiac River, on the east by the Valley Service Road (Stillman Avenue), on the south by an active sand and gravel mining operation, and on the north by vacant land (Figure 1). The site is transected by a Connecticut Department of Transportation (DOT) Drainage Channel, which flows westerly to the river. The southern portion of the site until recently was used as a sand and gravel mining area and is still used for processing material mined from the property to the south. In addition, part of the northern portion of the site was used for borrow material for the embankments of Interstate 91. The results of these and other past activities have been to reduce the natural elevations of the site from a range of +20 to +60 feet mean sea level (MSL), to the current -18 feet MSL in the ponds on the southern portion of the site, and to approximately +10 to +20 feet elsewhere on the site (see Appendix A: Geology). At the extreme northern end of the site and along the Quinnipiac River grades have not been modified. The resulting berm along the Quinnipiac River is broken in two locations, allowing stormwater to periodically pass through the site. If the DOT channel were piped through the site and the openings in the berm were closed, the site would not be subject to flooding.

Flooding conditions in the Quinnipiac River have recently been studied in the "North Haven Flood Insurance Study, March 1980", prepared by C.E. McGuire, Inc. for the U.S. Department of Housing and Urban Development, Federal Insurance Administration. This study, using standard FIA methodology for hydrologic and hydraulic analysis, determined surface water profiles along

the Quinnipiac River under current conditions of development, and computed a floodway (encroachment line) which assumes encroachment of both banks of the river. The floodway is defined as that area which conveys floodwater downstream. Encroachment lines are the boundaries which define the floodway in a manner which would produce a reasonable maximum increase of 1 foot in water elevation at the upstream limit of study during the 100-year flood (the accepted standard FIA measure). The purpose of this computation is to delineate a fringe flood plain, defined as the area between the encroachment line and the 100-year flood line, which may be considered for development without significant flooding impact. (Figure 2)

The results of the Flood Insurance Study show water elevations at the Mall site under current conditions as presented in Table 1:

Table 1

Approximate Water Elevation in the Quinnipiac River at the Mall Site

Flood Frequency	South Boundary (in feet)	North Boundary (in feet)
10 year	10.1	10.7
50 year	11.7	12.1
100 year	12.7	12.9

Considering the existing topography and the above-water elevations in the Quinnipiac River, portions of the site currently flood with water which enters through the openings in the berm at the center and southern ends of the site. High occurrence (e.g., 6-month or 1-year frequency) floods were reviewed and found to remain within the river banks. Once flooded, the site does

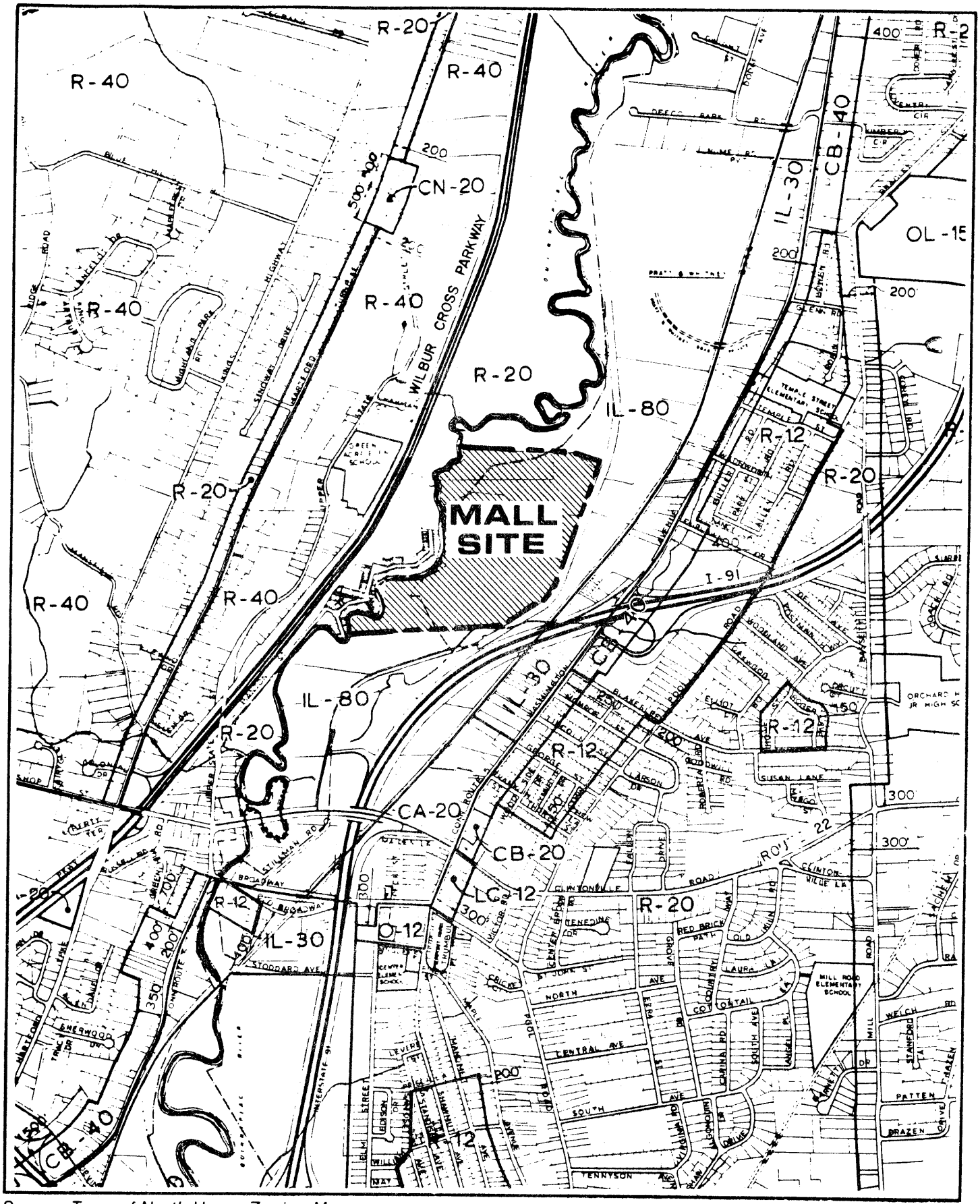
not convey flood waters because of the limited connections with the river. Although some water may flow in at the central opening and exit at the southern opening due to the hydraulic gradient of the river over the length of the site, the DOT Channel also discharges into the central opening, thus reducing any conveyance potential of the site.

Since the maximum elevation at the site during the 100-year flood is 12.9 feet (average from north to south of 12.8 feet), only approximately half of the site would flood to a depth averaging 3 feet. This flooding is a direct result of the past excavation which has significantly reduced the grades in the central and southern portion of the site. With the exception of the breaks, the undisturbed northern portion of the site and the berm along the River are above these flood levels.

PROPOSED ACTION

The proposed action on the site consists of construction of a shopping mall with four department stores, together with the required on-grade parking. A stormwater detention pond is also proposed as an integral part of the project. The Mall and parking areas would cover approximately 78 acres of the 117.5-acre site, with the detention pond occupying an additional 16.5 acres. The remaining 23 acres of the site would remain largely undisturbed.

In developing the Mall site, the grade would be raised from the existing +10 to +20 feet to between +12 and +32 feet to reduce flooding of the developed site. The finished grades would be below the original grades



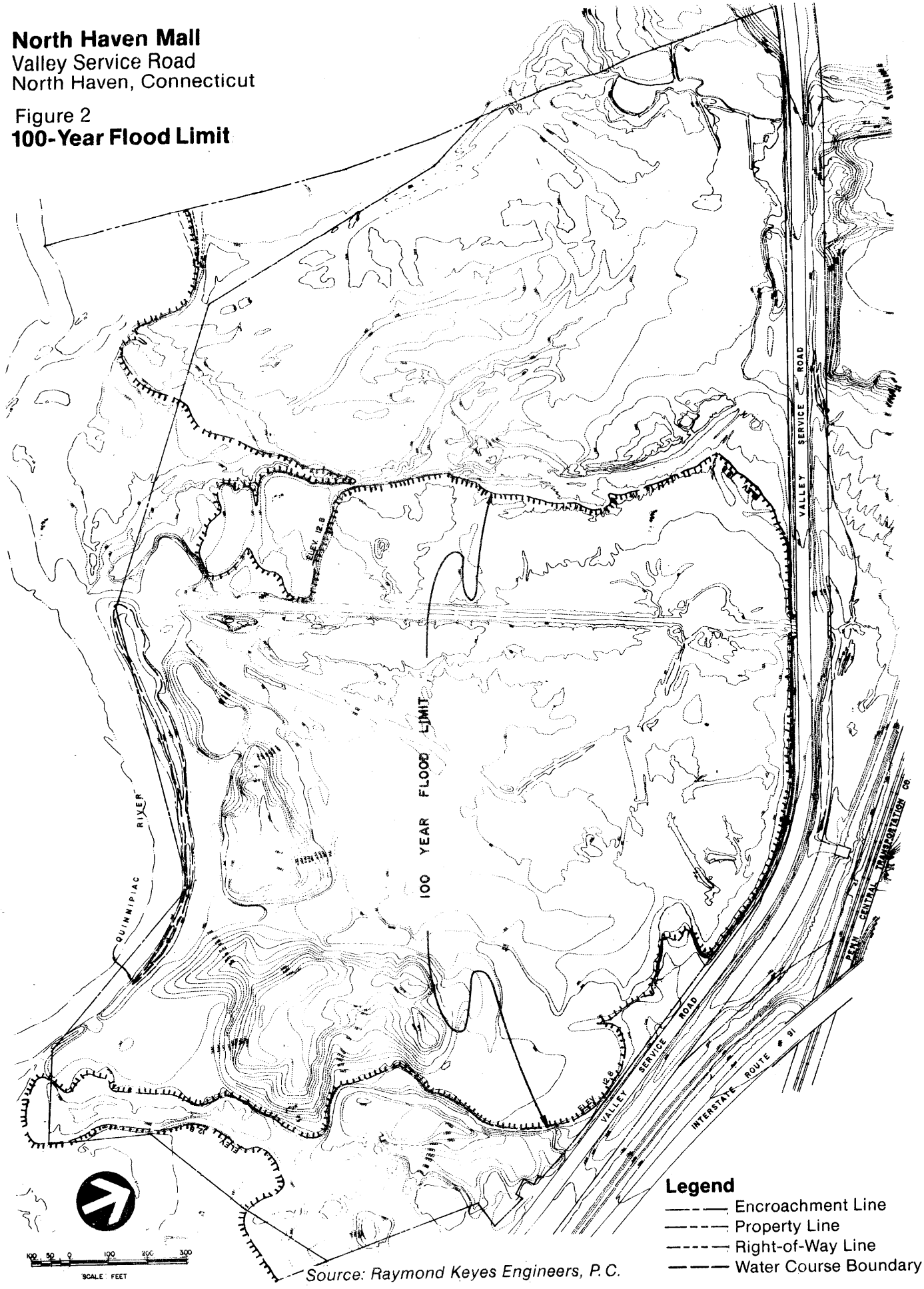
Source: Town of North Haven Zoning Map

North Haven Mall
Valley Service Road
North Haven, Connecticut

Figure 1
Site Location

North Haven Mall
Valley Service Road
North Haven, Connecticut

Figure 2
100-Year Flood Limit



Source: Raymond Keyes Engineers, P.C.

of the site, prior to its use as a sand and gravel mining source and as a borrow site for I-91.

The area that would be filled in development of the Mall site is outside the channel encroachment line which defines the floodway limit.

Site storage during the 2-, 10-, 50-, and 100- year flood events is presented in Table 2. Existing site storage includes all storage on the 117.5-acre site. Developed site storage considers both the storage available in the proposed pond and the additional storage associated with the parking lot and piped drainage system. Areas of the site that would not be filled and the relocated DOT drainage channel were not included. For the 100-year flood, for example, the areas of the site not filled would amount to 51.8 acre-feet of storage. The net loss of storage during the 2-, 10-, 50-, and 100-year flood events, excluding consideration of the areas of the site not filled, is also presented in Table 2.

Table 2

Flood Water Storage at the

North Haven Mall Site

Flood Frequency	Existing Site (acre-feet)	Developed Site (acre-feet)	Net Loss In Storage (acre-feet)
2 year	81.4	34.1	47.3
10 year	180.0	63.4	116.6
50 year	251.2	81.6	169.6
100 year	306.3	92.3	214.0

The Stormwater Management Plan (see Appendix E: Stormwater Management) consists of relocating the existing DOT channel to discharge through the 16.5-acre detention pond, and installing a piped drainage system to collect and transport stormwater from roof and parking areas to the detention pond (for 75 percent of the 78 acres) and to the Quinnipiac River (for 25 percent of the developed area in the northwestern quadrant).

Peak stormwater flows leaving the Mall site (including stormwater from the 830 acre drainage area east of the site, which would flow through the detention pond via the relocated DOT channel) would be reduced over that which currently occurs for all but small storms. Table 3 presents the magnitude of stormwater flows which would enter the Quinnipiac River and the attenuation of peak flows which would be achieved by the Stormwater Management Plan.

Table 3

Stormwater Flows Discharging from the North Haven Mall Site

(from Appendix E: Stormwater Management)

Rainfall Frequency	Pre-Development Peak Flow (cfs)	Post-Develoment Peak Flow (cfs)	Percent Attenuation (%)
2 years	140	146	-4.3
10 years	327	269	+17.7
50 years	553	350	+36.7
100 years	669	483	+30.9

IMPACT ASSESSMENT

The impact analysis of construction of the North Haven Mall upon flooding in the Quinnipiac River considers:

1. Increased peak flows and resulting increase in water levels downstream of the Mall site due to reduction in storage volume on the site associated with filling (hydrologic analysis).

2. Increased water levels in the Qunnipiac River upstream of the Mall site due to a reduction in the conveyance capacity of the river resulting from filling of the site associated with the mall development (hydraulic analysis).

The results of the analysis of flooding analyzed herein are supplemented by an analysis of the sensitivity of the Quinnipiac River to storage loss associated with the failure of the Wallingford Dam (see Appendix G: Wallingford Dam Study).

General Methodology

Flooding impacts in the Quinnipiac River were determined by comparing the peak river flow and associated hydrographs to the resulting river water profiles for different flood frequencies and different conditions of development along the river. The frequencies used for analysis are the 2-, 10-, 50-, and 100-year floods. Floods with a higher frequency (once in 6 months

and 1 year) were reviewed and found to remain within the river channel and were, therefore, not analyzed further. The development conditions analyzed were:

1. Present conditions along the river.

2. Existing conditions plus the proposed North Haven Mall development.

3. Potential development within encroachment lines in the Town of North Haven (approximately 3 miles up and downstream of the Mall site).

4. Full encroachment up to the floodway line in the Town as determined in the Flood Insurance Study.

The hydrologic and hydraulic conditions in the Quinnipiac River were determined for each flood frequency and development condition. The hydrologic analysis consisted of routing the flood hydrograph through North Haven and determining peak flows at various points along the river. This analysis determined the effects of removing storage from the river basin upon the peak flow. The hydraulic analysis consisted of computing the resulting water surface profiles for the same frequency floods and development conditions.

Hydrologic Analysis

The hydrologic analysis presents the changes to the hydrograph that occur under the different development conditions for the flood frequencies

of 2, 10, 50, and 100 years. For existing conditions of development, the peak flows were derived from the "North Haven Flood Insurance Study, March 1980" for the 10-, 50-, and 100-year frequencies at the southern Town line and at Sackett Point Road. Using these data, the 2-year flood frequency peak flow was derived.

The characteristics of the hydrograph (i.e., time to peak, base length, and shape) were generated from historic gaging data at the Wallingford gage, located approximately one mile upstream from the Town of North Haven line. The time to peak was determined to be 12 hours and the base 7 days. The time to peak is not measured from the onset of rain, but rather is the time from the beginning of increased flow. There is a lag of approximately 9 hours from the onset of rain until the river flows begin to rise.

The hydrographs were routed through the Quinnipiac River using the Corps of Engineers' HEC-1 Flood Hydrograph Computer Program. The existing conditions were modeled by using both the Muskingum and modified PULS methods. The Muskingum method was used for the long reaches upstream and downstream of the proposed Mall site. The Muskingum method uses coefficients to represent the channel and flood plain characteristics and was used for all hydrological analyses, except to determine the impact of the proposed Mall alone with existing development.

The use of the Muskingum method for the conditions of potential development and full encroachment is conservative in that the analysis assumed loss

of all storage for all properties. This is not probable as it is likely that other river front developments would be similar to the Mall (i.e., a portion of the existing storage is retained). These two development conditions are identical except that full encroachment covers the entire Town while the potential development condition encroaches the river to the south only to Sackett Point Road.

For the assessment of the impact of the Mall alone, the storage-elevation relationship used in the modified PULS method was estimated for existing conditions as presented in Table 4. The storage estimated was somewhat less than actual site storage. For the developed site, it was assumed that there would be no storage, where in fact there would be storage in the detention pond, parking lot, piped drainage system and the relocated DOT drainage channel. The net result of these two assumptions is to exaggerate any impact of the Mall development upon peak flows in the Quinnipiac River.

The results of the hydrologic analysis are presented in Table 5. These results show that for existing conditions and for the Mall impact alone, there would be no difference in peak flow, in spite of exaggerating the impact by conservative assumptions. This results because of the small volume of storage available at the site relative to the total volume of the flood. For example, the 240 acre-feet of assumed storage for the 100-year flood is approximately 1 percent of the total flood volume. Thus, filling of the Mall site would result in no change in river flows, with the peak flow during the 100-year flood remaining at 6700 cfs at the southern Town line.

Table 4

Storage at North Haven Mall Site

Utilized in Hydrological Analysis of

the Quinnipiac River

Flood Frequency	Existing Site Storage		Developed Site Storage	
	Actual (acre-feet)	Utilized* (acre-feet)	Actual** (acre-feet)	Utilized (acre-feet)
2 year	81.4	50	34.1	0
10 year	180.0	125	63.4	0
50 year	251.2	190	81.6	0
100 year	306.3	240	92.3	0

* Utilized in hydraulic analysis for prediction of increased rates of flow due to loss of storage in the Quinnipiac River.

** Excludes storage in areas of the site which would not be filled for the 100-year flood, amounting to 51.8 acre-feet.

Table 5

Peak Discharges in the Quinnipiac River

Location	Drainage Area	Flood Frequency	Existing Condition (cfs)	Existing Condition With Mall (cfs)	Likely Encroachment Within 3 Miles of Mall (cfs)	Full Encroachment (cfs)
Southern Town Line	160	100	6700	6700	6860	6991
		50	5800	5800	5939	6053
		10	3940	3940	4035	4111
		2	2050	2050	2099	2139
Sackett Point	131	100	5950	5950	6110	6110
		50	5150	5150	5289	5289
		10	3500	3500	3595	3595
		2	1800	1800	1849	1849
Mall Site	125	100	5750	5750	5850	5850
		50	4980	4980	5088	5088
		10	3380	3380	3463	3463
		2	1760	1760	1788	1788
Northern Town Line	110	100	5270	5270	5270	5270
		50	4570	4570	4570	4570
		10	3100	3100	3100	3100
		2	1610	1610	1610	1610

The maximum change in river flow under a fully encroached condition occurs at the furthest downstream point analyzed, the southern town line, for the 100-year flood where the flow would increase from 6,700 to 6,991 cfs. Based upon conservative assumptions, this would represent a 4 percent increase in peak flow. Again, the assumptions tend to exaggerate the increase in peak flow.

The conclusion drawn from the hydrologic analysis is that the loss of storage from the Mall site would have no measurable effect upon flood flows in the Quinnipiac River. Additionally, it is concluded that the cumulative impact of all potential development along the Quinnipiac River in the Town of North Haven would not be significant in terms of peak flows, since the river is relatively insensitive to changes in channel storage.

To further put the effects of site flood storage into perspective, the impacts of the storage available at Community Lake prior to the failure of the Wallingford Dam were analyzed (Appendix G: Wallingford Dam Study). The storage available prior to failure, computed from topographic maps, is presented in Table 6. This storage is considerably larger than the proposed site storage. Analysis of the hydrographs for the 2-, 10-, 50-, and 100-year floods with and without the dam showed no significant change in peak flow, with the maximum change for the 2-year storm of only 1.2 percent. The reason for the lack of peak flow attenuation by storage in the Quinnipiac River stems, in large part, from the rather flat hydrograph characteristic of the basin. A very large amount of channel storage is necessary to achieve any significant reduction in peak flows.

Table 6

Peak Flow and Storage

Wallingford Dam Sensitivity Analysis

Flood Frequency	Peak** Flow Rate w/o Dam (cfs)	Peak** Flow Rate w/Dam (cfs)	Percent Attenutation At Peak Flow (%)	Peak Storage Available w/Dam (acre-feet)	Existing Peak Storage Available Mall Site* (acre-feet)
2 year	1,630	1,610	1.2	252.5	81.4
10 year	3,100	3,100	0.0	417.9	180.0
50 year	4,570	4,570	0.0	562.4	251.2
100 year	5,270	5,250	0.4	629.0	306.3

* See Table 4
** As computed at Wallingford OSGS Gage.

The "flat hydrograph" is not typical of streams in New England but is more characteristic of coastal plains as they occur throughout the eastern seaboard (e.g., pine lands of New Jersey). The flatness of a hydrograph usually results from a large amount of channel storage available in areas with little relief and very porous sandy soils. Typically, New England upland areas have steep slopes and clayey soils which result in rapid runoff and, therefore, peaky hydrographs.

Hydraulic Analysis

Using the flows predicted in the hydrological analysis for the 2-, 10-, 50-, and 100-year flood for each condition of development, water surface profiles were computed using the Corps of Engineers' HEC-2 Backwater Computer Program. For the hydraulic impact analysis, the same four conditions previously outlined were utilized. These development conditions were as follows: (1) existing development along the river in the Town of North Haven; (2) existing development with the proposed North Haven Mall; (3) encroachment of all undeveloped property along the river in the Town of North Haven except for the Quinnipiac River State Park, which is not likely to be developed (already developed properties were also treated as not likely to be further developed); and (4) full encroachment of all properties along the river in the Town of North Haven up to the floodway line. Information concerning existing development was obtained from the Town of North Haven Planning Department.

The results of the hydraulic analysis are presented in Table 7 as water elevations at selected points along the Quinnipiac River for the different development conditions and flood frequencies. The depth of water, while

TABLE 7

Water Surface Elevations

in the

Quinnipiac River

Location	Flood Frequency	Existing Conditions (feet)	Existing w/Mall (feet)	All Likely Development in Town of N. Haven (feet)	Full Encroachment in Town of N. Haven (feet)
Southern** Town Line (X-Sect.A)***	2	3.60	3.60	3.88*	4.00*
	10	3.60	3.60	3.78*	3.81*
	50	3.60	3.60	3.71	3.84
	100	3.60	3.60	3.71	3.84
Sackett Point** Road (X-Sec. F)	2	4.44	4.44	4.65	4.83
	10	5.74	5.74	5.84	6.27
	50	6.74	6.74	6.82	7.84
	100	7.39	7.39	7.47	8.48
Mall Site (X-Sect. N)	2	8.36	8.36	8.48	8.50
	10	10.65	10.65	11.03	11.11
	50	12.05	12.05	12.61	13.05
	100	12.93	12.93	13.57	13.93
Northern Town Line (X-Sect. R)	2	16.99	16.99	17.03	17.03
	10	19.54	19.54	19.66	19.68
	50	21.39	21.39	21.52	21.54
	100	22.05	22.05	22.17	22.20

* Computational methodology uses the existing condition hydraulic gradient to compute the starting water surface elevation. At the first section, this methodology results in a higher elevation at the lower flows. This results because of the use of the same starting elevations for each flood frequency under existing conditions (mean high tide 3.60 feet). The actual water surface elevations at this section for smaller floods would be less than the high flow floods.

** These stations are subject to tidal surge. Stations above Broadway are not affected by tides and, therefore, elevations presented are maximums.

*** X-Sections refer to computational points in the computer model presented in documentation for this report.

varying somewhat, is essentially constant because the river under the flood frequencies studied is free flowing with surface elevations following the slope of the stream bed. Minor differences occur at constrictions such as exist near Broadway. The areas immediately upstream of constrictions would have slightly elevated water surfaces and are, therefore, more prone to flood damage. The area of Upper State Street north of Broadway to the intersection with Banton Street is subject to this localized phenomenon.

For existing conditions, the water surface elevations are essentially the same as presented in the Flood Insurance Study. Minor differences resulted from defining peak flows at several additional locations along the river.

For the case of the Mall development alone, there were no differences in water elevations over existing conditions. This results because the Mall site would not be a conveyance way for the Quinnipiac River and because the loss of site storage would have no measurable effect upon peak flow in the river.

For the development condition of all potential encroachments in the Town of North Haven, there resulted a slight increase in water levels throughout the Town of North Haven. These increases ranged from 0.04 feet up to 0.64 feet with the highest increase occurring near the Mall site for the 100-year flood. The primary cause of the increases in water elevation is encroachment south of the Mall site, particularly the areas south of Route 22, where development would reduce conveyance capacity and thus cause increased

flood depths upstream. North of the Mall site, the floodway increases in width because of the Quinnipiac River State Park and the already developed Pratt and Whitney properties, which are not likely to be encroached upon.

The final development condition analyzed, full encroachment of the river throughout the Town of North Haven, represents the extreme limit of flooding impacts possible due to development in the Town. This case assumes that all properties are filled to above flood levels out to the floodway (encroachment line). Under this improbable scenario, the water level increased from 0.14 feet to 1.1 feet, with the maximum increase occurring at Sackett Point Road where the river is constricted. The combination of conservative assumptions, for both storage and restriction in hydraulic conveyance, is such that this level of impact is not realistic but is presented as the upper limit of possible impacts.

Based upon the foregoing hydraulic analysis, it is concluded that the development of the proposed North Haven Mall would have no measurable impact upon flooding in the Quinnipiac River, because the river is not sensitive to such small losses in storage, and because the Mall site is not a conveyance way for flood waters.

The hydraulic analysis suggests that the Quinnipiac River is sensitive to loss of conveyance. Review of topographic maps of the Town of North Haven indicate that areas south of Broadway are most likely areas of loss of conveyance. Such loss would create a constriction which would cause potential flooding of upstream properties.

Summary of Impacts

The impact upon flooding from the development of the North Haven Mall was investigated with regard to: (1) increased flows from the site due to conversion of permeable areas to impervious surfaces (See Appendix E: Stormwater Management); (2) increased peak flows occurring in the Quinnipiac River resulting from loss of storage capacity from site filling; and (3) increased water levels in the river due to the increased peak flows and reduced carrying capacity of the river resulting from filling. These impacts were analyzed for existing conditions, for the Mall development alone, for all potential development in the Town of North Haven, and for full development (encroachment) in the Town of North Haven.

The result of these analyses shows no impact on flooding in the Quinnipiac River from the Mall development, and in fact, a net reduction in runoff flow rates into the river as a result of the Mall development.

The cumulative impact of development in the Town of North Haven on flooding is significant only when those properties which act as conveyance ways for flood waters are filled. The loss of storage from cumulative development does not have a significant impact on flooding since the peak flows are rather insensitive to the loss of storage in volumes available in the Town of North Haven. Any small impacts from cumulative storage loss can be mitigated by reconstruction of the failed Wallingford Dam, with modification to the spillway to maximize the storage characteristics of Community Lake.